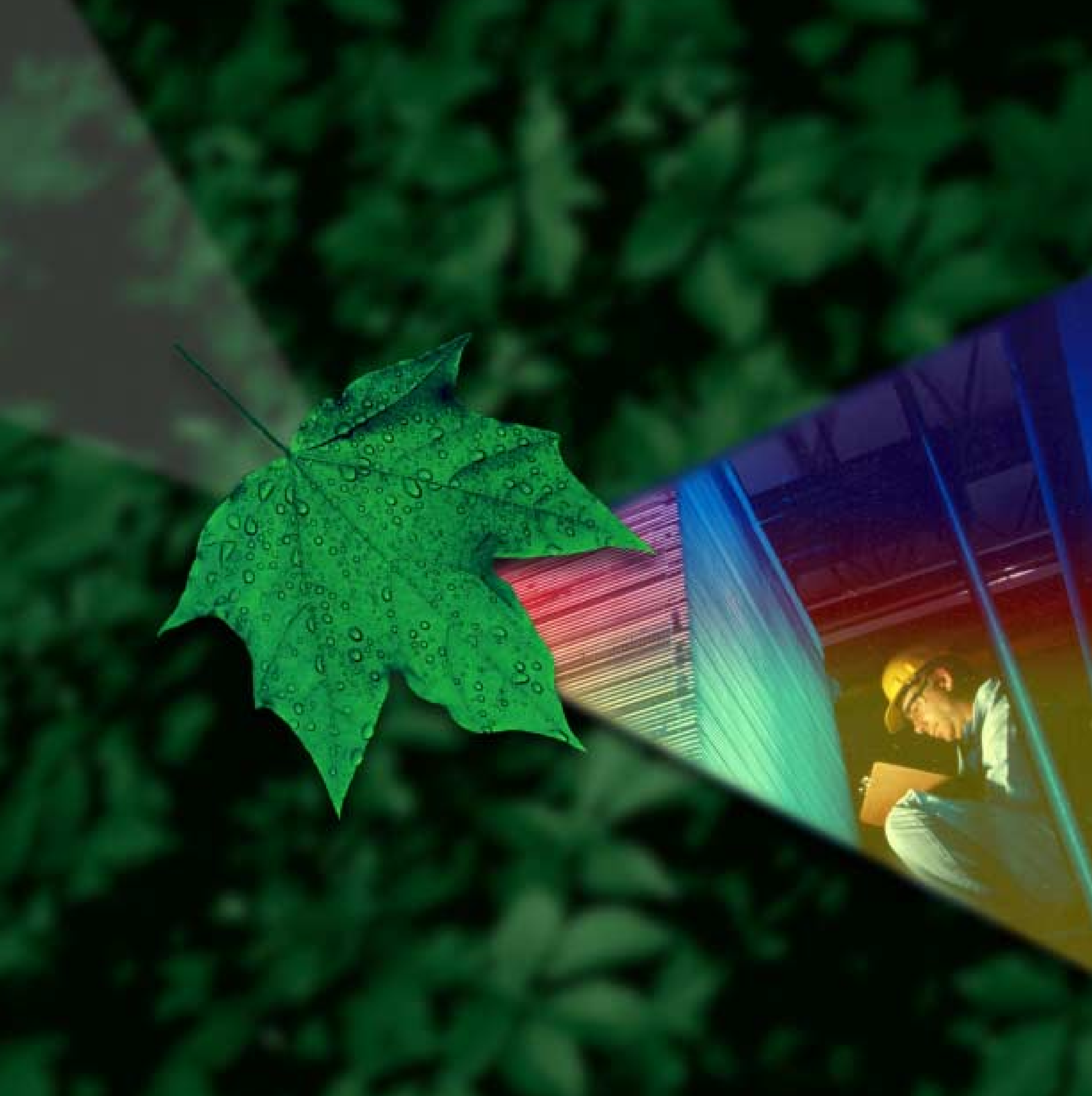
DISTRIBUTED GENERATION



PROVIDING RELIABLE, FLEXIBLE POWER

Introduction

Program Areas

- Second Generation Fuel Cells
- Vision 21 Fuel Cell/ Turbine Hybrids
- SECA Solid State Fuel Cell

A confluence of utility restructuring, technology evolution, public environmental policy, and an expanding electricity market are providing the impetus for distributed generation to become an important energy option in the new millennium.

Distributed generation is the strategic application of relatively small generating units (typically less than 30 MWe) at or near consumer sites to meet specific customer needs, to support economic operation of the existing power distribution grid, or both. Reliability of service and power quality are enhanced by proximity to the customer and efficiency is improved in on-site applications by using the heat from power generation.

While addressing distributed generation potential in general, the program presented here focuses on fuel cells and the U.S. Department of Energy (DOE) efforts to bring them into the marketplace.

The Distributed Generation program contributes to two of the energy challenges that are being addressed in the National Energy Strategy: (1) improving the environmental acceptability of energy production and use by improving the efficiency and economics of the use of natural gas through the use of advanced technologies, and (2) increasing the competitiveness and reliability of U.S. energy systems. This is achieved through the strategy of encouraging the development and deployment of distributed power technologies to satisfy market forces for smaller, modular power technologies that can be installed quickly, close to consumer demand centers.

Fuel cells offer a distributed generation option with the potential to revolutionize power generation. Fuel cell systems have few moving parts, making them reliable as well as quiet. No solid wastes are produced and pollutant emissions are negligible. The potential electrical efficiencies can reduce carbon dioxide emissions by 50 percent compared to existing power plants. Moreover, their modular construction and electrochemical processing allow suppliers to match demand and maintain efficiency. Fuel cells are beginning to enter the market, but require additional research and development to realize widespread deployment.

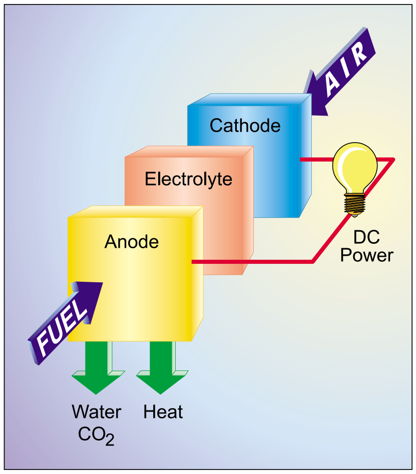
Phosphoric acid fuel cells (manufactured by the ONSI Corporation) have been sited, permitted, installed, started, operated, and maintained in a real-world environment. The fleet of ONSI fuel cells continues to demonstrate reliable, safe operation in a variety of climates, applications, and service scenarios. Here, an ONSI fuel cell unit is being installed in a location in Times Square in New York City. [Photo courtesy of ONSI Corporation]

Fuel Cell Defined

Fuel cells work without combustion and its environmental side effects. Power is produced electrochemically by passing a hydrogen-rich fuel over an anode, and air over a cathode, and separating the two by an electrolyte. In producing electricity, the only by-products are heat, water, and CO_2. Hydrogen fuel can come from a variety of hydrocarbon resources by subjecting them to steam under pressure (called reforming or gasification). The electrolyte, which induces the fuel cells electrochemical reactions, can be composed of liquid or solid media. The media used differentiates the type of fuel cell.

The direct electrochemical reaction in lieu of moving parts to produce electricity has inherent efficiency advantages. Overall system efficiency can be enhanced by using the high energy heat derived from the fuel cell reactions either in combined heat and power (CHP) or in combined-cycle applications (generating steam for additional electric power). The CO_2 is in concentrated form, which facilitates capture for recycling or sequestration. The absence of moving parts results in very low noise levels. Stacking of cells to obtain a usable voltage and power output allows fuel cells to be built to match specific power needs.

Fuel cell systems also require a power conditioner to convert direct current (DC) from the fuel cell to the more commonly used alternating current.



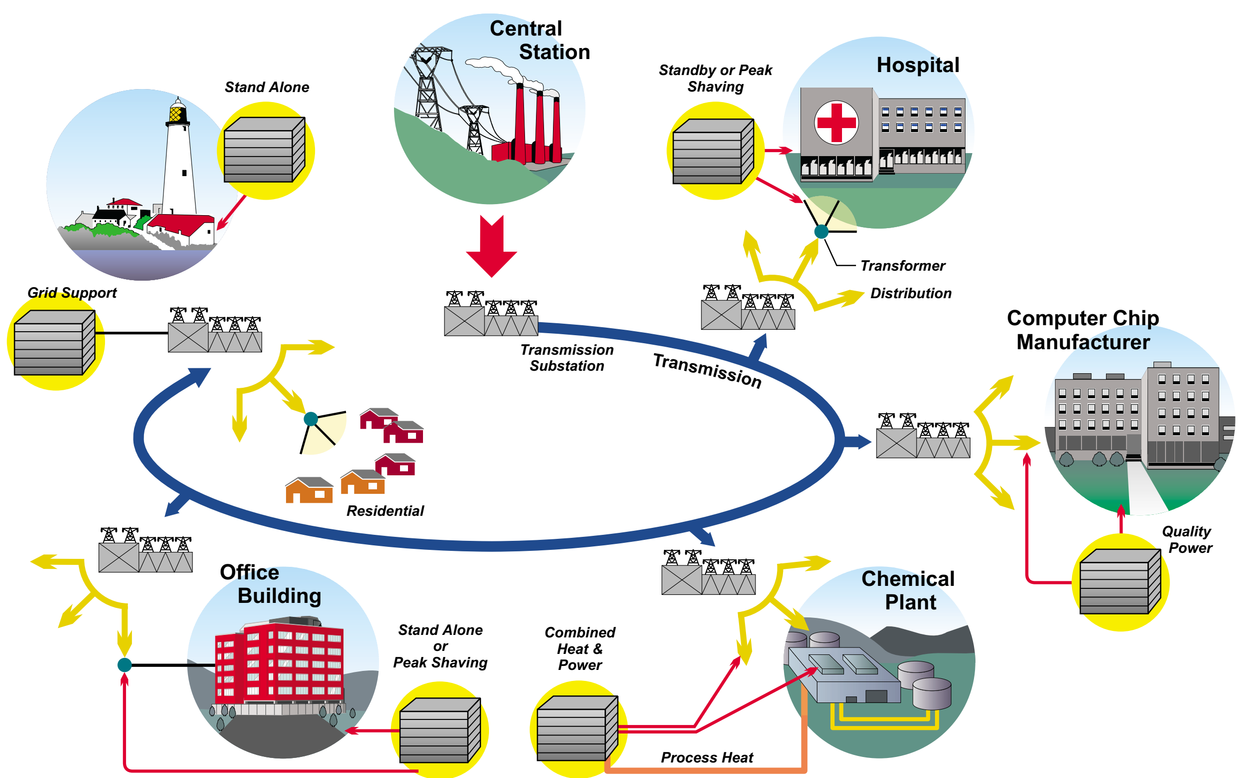
OVERVIEW

Applications

There are a number of basic applications, outlined below, that represent typical patterns of services and benefits derived from distributed generation.

- **Standby Power.** Standby power is used for customers that cannot tolerate interruption of service for either public health and safety reasons, or where outage costs are unacceptably high. Since most outages occur as a result of storm or accident related transmission and distribution (T&D) system breakdown, on-site standby generators are installed at locations such as hospitals, water pumping stations, and electronic-dependent manufacturing facilities.
- **Combined Heat and Power.** Power generation technologies create a large amount of heat in converting fuel to electricity. If located at or near a customer's site, heat from the power generator can be used by the customer in what are called CHP or cogeneration applications. CHP significantly increases system efficiency when applied to mid- to high-thermal use customers such as process industries, large office buildings, and hospitals.
- **Peak Shaving.** Power costs fluctuate rapidly depending upon demand and generation availability. These fluctuations are converted into seasonal and daily time-of-use rate categories such as on-peak, off-peak, or shoulder rates. Customer use of distributed generation during relatively high-cost on-peak periods is called peak shaving. Peak shaving benefits the energy supplier as well, when energy costs approach energy prices.
- **Grid Support.** The power grid is an integrated network of generation, high voltage transmission, substations, and local distribution. Strategic placement of distributed generation can provide system benefits and precludes the need for expensive upgrades.

Distributed Generation Applications



OVERVIEW

Drivers

While central power systems remain critical to the Nation's energy supply, their flexibility to adjust to changing energy needs is limited.

Robotic fabrication, as shown here, is becoming commonplace in the manufacturing industry and is mandating high-quality power for the associated electronic components.

Because central power is composed of large, capital-intensive plants and a T&D grid to disperse electricity, significant investments of time and money are required to increase capacity. Distributed generation, on the other hand, complements central power by: (1) providing a relatively low capital cost response to incremental increases in power demand; (2) avoiding T&D capacity upgrades by locating power where it is most needed; and (3) providing the flexibility to put surplus power back into the grid at user sites.

Utility restructuring opens energy markets, allowing the customer to choose the energy provider, method of delivery, and attendant services. The market forces favor small, modular power technologies that can be installed quickly in response to market signals. This restructuring comes at a time when:

- Demand for electricity is escalating domestically and internationally;
- Impressive gains have been made in the cost and performance of small, modular distributed generation technologies;
- Regional and global environmental concerns have placed a premium on efficiency and environmental performance; and
- Concerns have grown regarding the reliability and quality of centralized electric power generators.

During recent years the term "new economy" has emerged in the nation's lexicon to describe the rapidly growing electric, telecommunication, biotechnology, and computer industries. Coincident with the explosive growth in the new economy comes the deregulation of the electric utility industry and the emphasis on competition in wholesale power markets, along with pressure to keep costs low. Deregulation has contributed to lower capacity margins in some regions of the country with the attendant increase in likelihood of power outages and reduction in power quality that can deal a crippling blow to the bottom line of new economy firms that must rely on reliable, high quality power sources. Industries are examining alternatives to reliance on the conventional grid supplied power. Distributed power generation systems provide an effective alternative for use by new economy industries, which represent an enormous market opportunity.

Worldwide demand for electricity is expected to double in the next twenty years. International markets are expected to expand rapidly, increasing nine trillion kilowatt-hours by 2020. Much of this increase is likely to occur in developing countries where the electricity infrastructure is modest or non-existent. The market potential in remote power generation is very large and represents a major opportunity for U.S. equipment manufacturers, suppliers, and power developers of distributed generation.

Accomplishments

In fiscal year 1995, fuels cells became an integral part of the federal government's strategy to address global climate change concerns.

Through a Defense Department appropriations bill, Congress authorized the Climate Change Fuel Cell program — a joint effort of the U.S. Department of Defense (DoD) and DOE to accelerate commercialization of fuel cells. The National Energy Technology Laboratory (NETL) is responsible for implementing the program, which is managed by the U.S. Army Construction Engineering Research Laboratory.

The program is a key element of the Federal Administration's Climate Change Action Plan designed to curb greenhouse gas emissions through expedited deployment of highly efficient, clean technologies. Defense Department goals were addressed as well by helping to create a fuel cell manufacturing capability critical to their energy security and readiness needs. The Climate Change Fuel Cell program leveraged cooperative government/industry fuel cell development efforts and resulted in successful commercialization of a first generation of fuel cells using a phosphoric acid electrolyte. To date, there have been over 200 turnkey installations of 200-kW phosphoric acid fuel cell (PAFC) units, using ONSI PC25 technology around the world. PAFC systems operate at temperatures sufficient for providing hot water and space heating and have electrical efficiencies ranging from 40–45 percent on a lower heating value (LHV) basis.

Development of second generation high-temperature fuel cells is proceeding efficiently. Both molten carbonate fuel cells (MCFCs) and solid oxide fuel cells (SOFCs) are in advanced stages of development. These high temperature systems offer fuel-to-electricity efficiencies of 50–60 percent and overall thermal efficiencies of 80 percent in CHP and combined-cycle applications. The NETL is working with FuelCell Energy to bring the MCFC to commercial fruition, and is working with Siemens Westinghouse Power Corporation (SWPC) to commercialize the SOFC. Both participants have demonstrated their technologies and shown the promise needed to proceed with commercial prototype demonstrations.

A FuelCell Energy (formerly Energy Research Corp) molten carbonate fuel cell

ACTIVITIES

High-temperature MCFCs and SOFCs are entering the commercial demonstration phase.

High temperatures enable internal reforming of fuels, fuel-to-electricity efficiency up to 60 percent LHV, and production of high quality heat for CHP and combined-cycle applications. Moreover, these units either tolerate or use reformed fuel constituents such as carbon monoxide, which represents a poison to PAFCs and proton exchange membrane fuel cells (PEMs). The heat developed in producing electricity also makes MCFCs and SOFCs ideal candidates for integration with gas turbines.

100-kW SOFC cogeneration system operating in the Netherlands, built by Siemens Westinghouse

Market entry for natural gas-based MCFCs and SOFCs is planned for 2003. Demonstration objectives include reducing capital costs to $1,500/kW. Subsequent to market entry, capital costs are expected to decline as manufacturing capacity and capability increase. Follow-on testing will address expanding the fuel options by operating on coal-derived synthesis gas.

Development of turbine/fuel cell hybrids using MCFCs and SOFCs in combination with gas turbines is underway. The synergy offers the potential for fuel-to-electricity efficiencies of 60–70 percent. Systems studies by SWPC, Rolls Royce Allison, FuelCell Energy, Solar Systems, and Northern Research and Engineering Corporation laid the foundation for follow-on efforts. DOE selected FuelCell Energy-Capstone Turbine and Rolls Royce Allison to conduct 280-kW hybrid demonstrations and develop designs for a 40-MW hybrid system. DOE also has agreements with SWPC to conduct hybrid demonstrations at 250-kW and 1-MW scales. The U.S. Environmental Protection Agency (EPA) and the European Commission are to partner with DOE on the demonstrations. Commercial application of a 70 percent efficient turbine/fuel cell hybrid is planned for 2010.

Under a Solid State Energy Conversion Alliance (SECA) initiative, a solid state fuel cell is being developed. The SECA initiative is attempting to break the capital cost barrier, ultimately producing fuel cells with a factory cost of less than $400/kW for stationary power generation and even lower for transportation applications. The key will be the *mass customization* of ceramic-based fuel cells using techniques adapted from recent revolutionary advances in solid state electronics, materials, and fuel cell designs.

SECA is structured to accelerate the development of the industrial base needed to produce low-cost solid state fuel cells in the near term. By leveraging government and industry resources, SECA objectives are to introduce an $800/kW solid state fuel cell having between 40 percent to 60 percent fuel-to-electricity efficiency within three years and a $400/kW fuel cell by 2010. The basic building block for this is a 5-kW module that can be combined like batteries to meet the particular power requirement. Ultimately, the SECA solid state fuel cell technology will become a key Vision 21 enabling technology.

LINKS AND CROSSCUTS

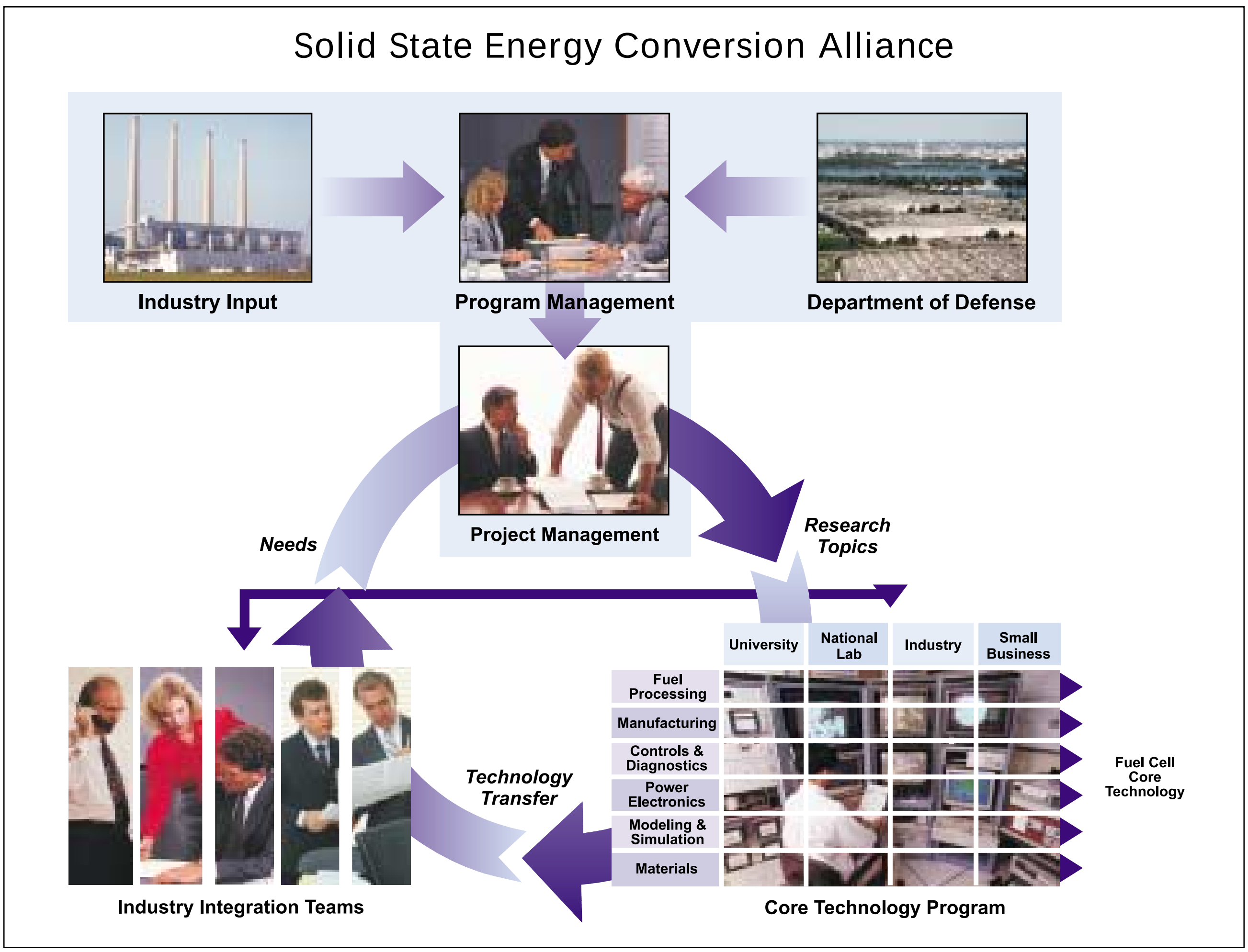
The Office of Fossil Energy (FE) and the Office of Energy Efficiency and Renewable Energy (EERE) jointly manage the DOE Distributed Generation Systems program. DOE's internal R&D council provides assistance in the management and implementation of the program.

Both FE and NETL are building an alliance of government agencies, commercial developers, universities, and materials laboratories committed to the development of low-cost, high-power-density solid state fuel cells for a broad range of applications. The alliance is SECA. SECA represents a new model for joint government and industry technology development. The structure of SECA is designed to leverage resources to overcome the most difficult technical barriers, while enabling industry to maintain a competitive posture. Two DOE national laboratories, NETL and Pacific Northwest National Laboratory (PNNL) are the driving forces behind SECA, providing the leadership, focus, and integration needed to bring solid-state fuel cell technology into near-term markets.

Both FE and the Department of Defense collaborate to accelerate the commercial deployment of fuel cells. Under this program, the Department of Defense provides \$1,000/kW of the cost of installing a PAFC. DOE administers the program, which to date has resulted in the installation of over 149 PAFCs.

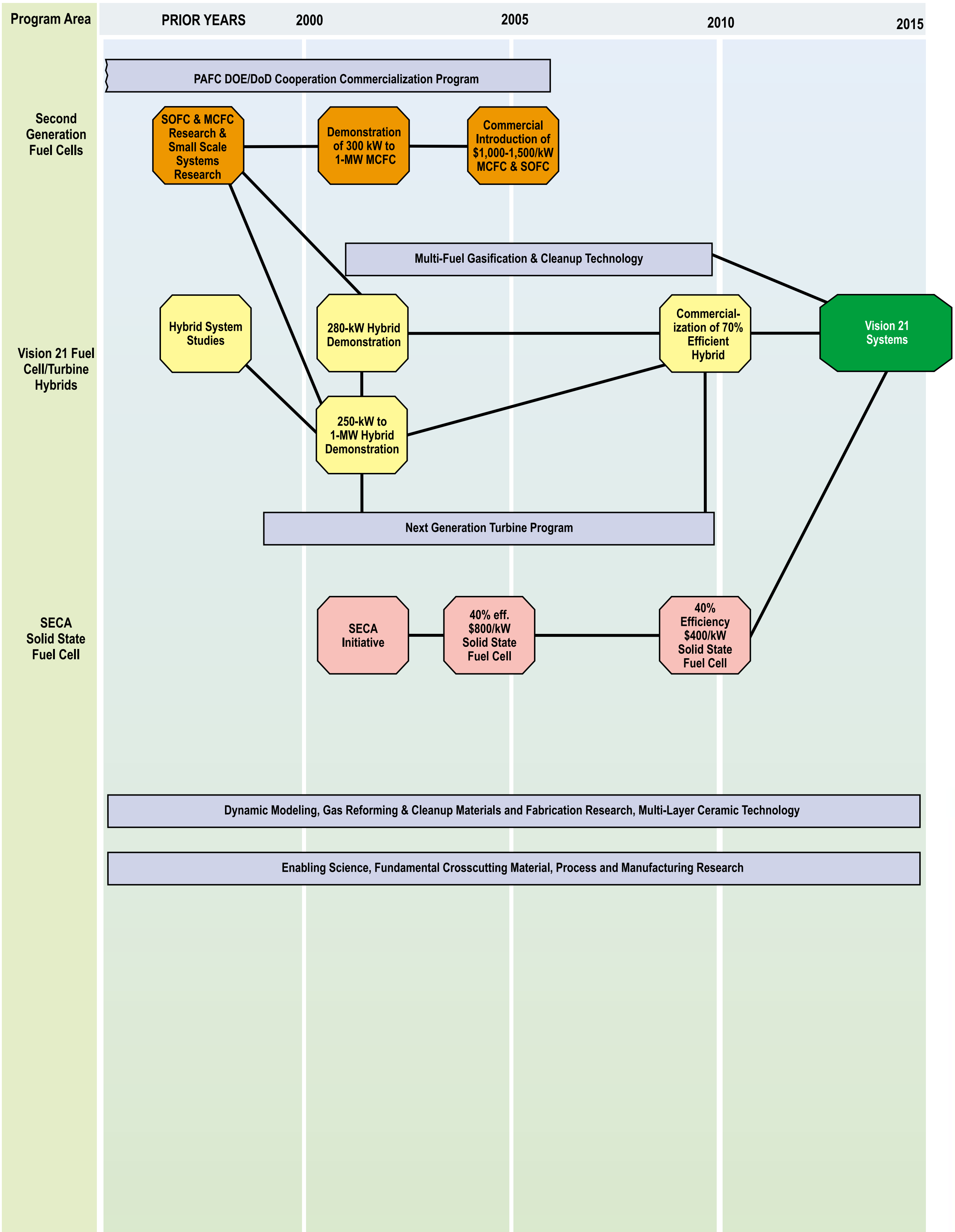
Argonne National Laboratory (ANL) and Oak Ridge National Laboratory (ORNL), along with NETL and PNNL, support all the activities previously discussed.

The adjacent roadmap summarizes activities under the four Distributed Generation Systems program areas and shows the interrelationships.



OVERVIEW

Distributed Generation Roadmap



OVERVIEW

Drivers

- Utility restructuring is underway, exacerbating concerns over reliability and quality of electric power.
- Electric power producers will seek energy ventures that are less capital-intensive, offer flexibility in siting, closely couple generation capacity to load growth, increase efficiency, and reduce environmental intrusion.
- Efficiency and environmental performance of small, modular systems have begun to exceed the performance of central station power systems in some applications.
- High quality and reliable power supplies are critical to many “new economy” industries employing highly sensitive electric components. Studies indicate that nationwide power fluctuations cause annual losses of $12–26 billion.
- Electric utilities will seek to reduce capital expenditures associated with installing and/or upgrading peaking generation capacity and transmission and distribution system expansion.
- Civil, military, and special requirements for electric power need to be met in environmentally sensitive and pristine areas where transmission and distribution systems are nonexistent and only zero pollutant emissions will be tolerated.
- Rapid growth is expected in the export market to bring electricity to an estimated two billion people in rural areas currently without access to a power grid.
- Fuel flexibility in power generation will provide the consumer with options to maintain low-cost electricity, even under the pressures of increased power demand and environmental concerns.
- Regional and global environmental objectives will continue to place a premium on efficiency and environmental performance.
- Fewer resources are being devoted to research and development by the utility industry.

Objectives

- In the near term (2003), assure the deployment of current and second-generation distributed generation systems. Ensure that these systems receive appropriate environmental credits and existing regulations do not serve as barriers to their use.
- In the midterm (to 2010), foster the development of advanced distributed generation systems including fuel cell/gas turbine hybrids with improved efficiency, environmental, and economic performance.
- In the midterm (to 2010), foster development, through SECA, of a 40–60 percent efficient $400/kW solid state fuel cell.
- In the long term (to 2015), develop high efficiency (up to 80 percent), near-zero emissions, low-cost distributed generation systems capable of operating on natural gas or gas derived from coal, biomass, or opportunity fuels.
- In the long term (to 2020), encourage the maximum use of advanced distributed generation systems that will permit U.S. industry to offer domestic and international users innovative approaches to achieving low-cost, environmentally benign distributed generation, meeting all reliability and power quality requirements independent of geographic location.

Strategies

- Continue cooperative efforts with DoD and industry to accelerate commercial deployment of phosphoric acid fuel cells.
- Develop, demonstrate and commercially introduce high temperature, natural gas-fueled molten carbonate fuel cells and solid oxide fuel cells capable of 50–60 percent efficiency in the multi-kilowatt range at a cost of $1,000–1,500/kW. (2003)
- Advance the SOFC/turbine hybrid through small-scale performance and environmental tests. (2003)
- Support the SECA goals of achieving fuel cell distributed generation solid-oxide technology of 5-kW modules basic blocks, with 40–60 percent efficiency, at a cost of $400 kW or less. (2010)
- Develop and demonstrate the fuel cell/turbine hybrids with efficiencies over 70 percent and commercially introduce coal-fueled, multi-megawatt power plants at competitive costs. (2010)
- Advance the critical, high-risk technology that will permit industry to establish the commercial viability of a low-cost, ultra-high efficiency (80 percent) Vision 21 hybrid. (2015–2020)

Performance Measures

- Complete construction for demonstration of a commercial scale 300-kW to 1-MW MCFC that will verify the commercial design for combined heat and power and distributed generation. (2001)
- Fully implement the SECA national level concept to achieve mass production of low-cost, technically superior ceramic fuel cell technology. (2001)
- Begin testing of a 300-kW to 1-MW SOFC/turbine hybrid commercial prototype in support of Vision 21. (2001)
- Achieve commercial introduction of natural gas-fueled high-temperature MCFC and SOFC at a cost of $1,000–1,500/kW. (2003)
- Have the gasification and gas cleanup technology in place to expand fuel cell fuels to coal, biomass, and municipal, forestry, and refinery wastes. (2010)
- Achieve SECA goal of $400/kW ceramic fuel cell modules with 40–60 percent efficiency and improved fuel flexibility. (2010)
- Introduce commercially-viable, near-term fuel cell/turbine hybrids capable of 70 percent efficiency. (2010)
- Introduce commercially, a Vision 21 hybrid at a cost of $400/kW, 80 percent efficiency, and near-zero emissions that is compatible with carbon sequestration technologies and stack life of five years. (2015)
- Establish stronger U.S. technology leadership position in multi-megawatt fuel cell/turbine hybrids using solid state fuel cells. (2015)

Distributed Generation Program Benefits

National Benefits

- Reduces greenhouse gas emissions through efficiency gains and potential renewable resource use;
- Responds to increasing energy demand and pollutant emission concerns while providing low-cost, reliable energy essential to maintaining competitiveness in the world market;
- Positions the United States to export distributed generation technologies in a rapidly growing world energy market, the largest portion of which is devoid of a transmission and distribution grid;
- Establishes a new industry worth billions of dollars in sales and hundreds of thousands of jobs; and
- Enhances productivity through improved reliability and quality of power delivered, valued at billions of dollars per year.

Supplier Benefits

- Limits capital exposure and risk because of the size, siting flexibility, and rapid installation time afforded by the small, modularly constructed, environmentally friendly, and fuel flexible systems;
- Avoids unnecessary capital expenditure by closely matching capacity increases to growth in demand;
- Avoids major investments in transmission and distribution system upgrades by siting new generation near the customer;
- Offers a relatively low-cost entry point into a competitive market; and
- Opens markets in remote areas without transmission and distribution systems, and in areas without power due to environmental concerns.

Customer Benefits

- Ensures reliability of energy supply, increasingly critical to business and industry in general, and essential to some where interruption of service is economically unacceptable or where health and safety are impacted;
- Provides the right energy solution at the right location;
- Provides the power quality needed in many industrial applications dependent upon sensitive electronic instrumentation and controls;
- Offers efficiency gains for on-site applications by avoiding line losses and using both electricity and the heat produced in power generation for processes or heating and air conditioning;
- Enables savings on electricity rates by self-generating during high-cost peak power periods, and adopting relatively low-cost interruptible power rates;
- Provides a stand-alone power option for areas where a transmission and distribution infrastructure do not exist or is too expensive to build;
- Allows power to be delivered in environmentally sensitive and pristine areas by having characteristically high efficiency and near-zero pollutant emissions;
- Affords customers a choice in satisfying their particular energy needs; and
- Provides siting flexibility by virtue of the small size, superior environmental performance, and fuel flexibility.

SECOND GENERATION FUEL CELLS

PERFORMANCE TARGETS

Efficiency: 50-60%

Cost: $1000-1,500/kW

Year: 2003

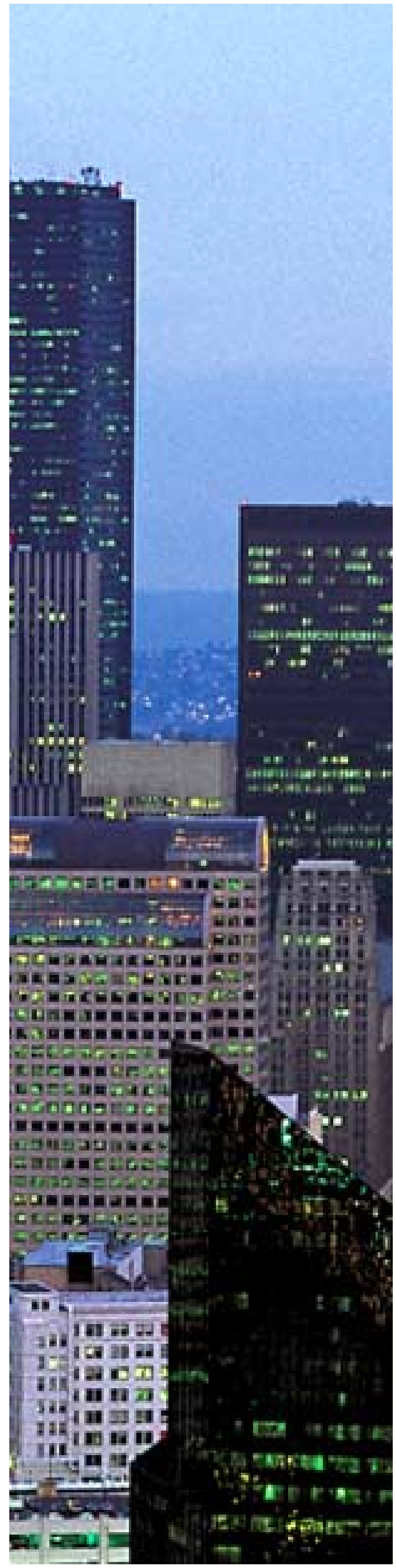
Phosphoric acid fuel cells (PAFCs) represent the current state-of-the-art in fuel cell technology.

While fuel-to-electricity efficiencies of PAFCs are reasonably high, 40–45 percent LHV, the 200 °C (400 °F) operating temperature limits thermal efficiency, the ability to internally reform fuels, and effective use in hybrid cycles (such as fuel cell/turbine hybrids) to further improve efficiency.

Two second generation, high-temperature fuel cells are in the final stages of development — molten carbonate fuel cells and solid oxide fuel cells. These systems offer both major improvements in stand-alone fuel-to-electricity efficiency, and overall thermal efficiency.

FuelCell Energy has developed an MCFC and brought the system to the point of commercial demonstration. The system operates at approximately 650 °C (1,200 °F) and offers fuel-to-electricity efficiencies of 50–60 percent LHV. The high temperature enables effective internal reforming of fuels, use in hybrid cycles, and thermal efficiencies up to 80 percent LHV in CHP and combined-cycle applications.

FuelCell Energy's first commercial prototype 250-kW MCFC full-size stack demonstration unit



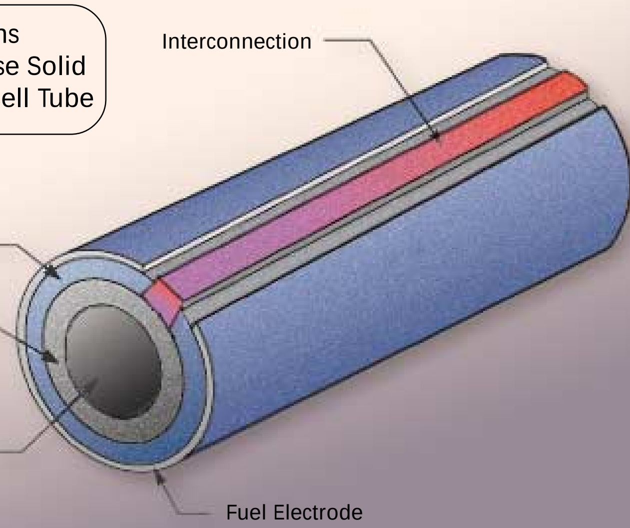
In parallel, Siemens Westinghouse has brought the SOFC to the commercial demonstration stage. SOFCs operate at temperatures up to 1,000 °C (1,800 °F) and also offer fuel-to-electricity efficiencies of 50–60 percent LHV. The temperature enhances internal fuel reforming, and hybrid cycle and thermal efficiency potential. The solid state ceramic construction enables the high temperatures, allows more flexibility in fuel choice, and contributes to stability and reliability.

In fiscal year 2001, an MCFC will be demonstrated at commercial scale, 300 kW to 1 MWe. The demonstration is expected to verify the commercial design of MCFC technology for distributed generation applications in 2003. As market acceptance and manufacturing capacity increase, natural gas-fueled MCFC plants in the multi-megawatt range will become available for central power applications.

SOFC technology is proceeding along two paths. As will be discussed in subsequent sections, an SOFC/turbine hybrid system is soon to undergo demonstration, and SOFC technology is to be a building block for a next generation of solid state fuel cells under the SECA initiative.

Follow-on testing of second-generation fuel cells will address expanding the fuel options by first operating on coal-derived synthesis gas. Gasification technologies using coal, petroleum coke, and waste fuels for power generation are currently experiencing market penetration. As these technologies mature, integrated gasification fuel cell systems become an obvious next step. Both MCFCs and SOFCs are compatible with carbon monoxide, a major constituent of synthesis gas, unlike PAFCs and PEMs (PEMs are another fuel cell option being considered for transportation and residential power applications).

Siemens Westinghouse Solid Oxide Fuel Cell Tube



P R O G R A M A R E A S

Vision 21 Fuel Cell/Turbine Hybrids

Performance Targets

Efficiency: 70% LHV

Cost: 20–25% lower than comparably sized fuel cell

Year: 2010

Siemens Westinghouse fuel cell/turbine hybrid system

The Vision 21 hybrid effort is conducted in coordination with the Next Generation Turbine (NGT) program.

The focus is on integration of the fuel cell and gas turbine into a single system that can achieve 70 percent efficiency LHV at a cost 20–25 percent lower than a comparably sized fuel cell.

Systems studies by SWPC, Rolls Royce Allison, FuelCell Energy, Solar Turbines, McDermott, and Northern Research and Engineering Corporation laid the foundation for follow-on efforts. NETL selected FuelCell Energy-Capstone Turbine and Rolls Royce Allison teams to:

- Evaluate fuel cell networking approaches in which fuel cells are used to “bottom” other fuel cells;
- Develop key system components including a modified anode exhaust oxidizer and heat exchange equipment;
- Demonstrate a 280-kW hybrid by 2003; and
- Complete a systems study for a 40-MW hybrid system.

In addition, SWPC has an agreement with DOE to conduct hybrid demonstrations at 250-kW and 1-MW scales, which are scheduled to start in 2001. SWPC, in conjunction with Praxair, will conduct a 30-month project to develop the technology leading to near-zero emissions Vision 21 power plants based on SOFC and ceramic ITM oxygen separation membranes.

Finally, a multi-disciplinary team led by the National Fuel Cell Research Center at the University of California at Irvine will define the systems engineering issues associated with the integration of key components and subsystems into Vision 21 power plants.

EPA and the European Commission are partnering with DOE on the demonstration projects. Other efforts include dynamic and detailed modeling and exploration of market issues.

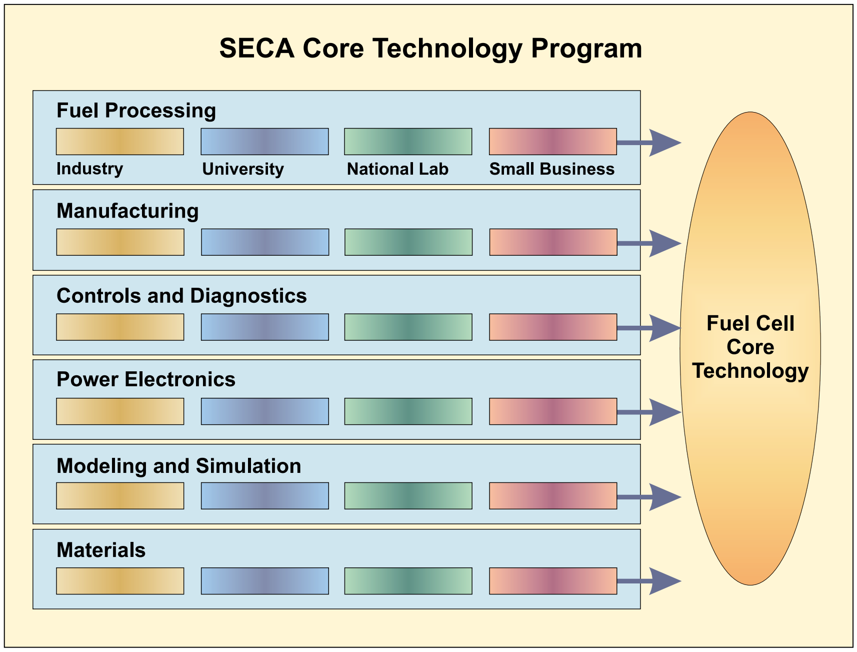
SECA Solid State Fuel Cell

Performance Targets

Efficiency: 40%–60%

Cost: $400/kW

Year: 2010



An initiative is underway to develop a solid state fuel cell offering low capital cost.

To achieve this goal, a unique public/private sector alliance has been forged and market targets broadened to accelerate the development of the industrial base needed to produce fuel cells at the targeted low-cost.

A convergence of technological advances and market forces has set the stage for the initiative. Advances in technology include: SOFC development, thin-film capabilities with solid state fuel cells, high power density enabling innovations (such as anode supported cells), compact fuel processing technology, improved power electronics at the device level, and integration of manufacturing technology from related industries (such as the semiconductor industry). Market forces include: incentives for distributed generation under utility deregulation, a commitment by the Department of Defense to use electric drive for future ship propulsion and to pursue "dual use" technology, and a move by the utility and transportation sectors to explore advanced technology options that address global climate concerns.

To effectively leverage the technology gains and market forces, SECA was formed. SECA comprises government agencies, commercial developers, universities, and National Laboratories committed to the development of low-cost, high power density, solid state fuel cells for a broad range of applications. Both NETL and PNNL are taking a leadership role to provide the focus and coordination needed to bring solid state fuel cells into near-term markets.

A driving force behind SECA is the accelerated development of the infrastructure to mass produce solid state fuel cells in the near term. A mass customization approach is being taken that involves development of standard fuel cell components for use in multiple market applications. Components encompass the fuel cell stack and balance-of-plant equipment. The basic building block will be a mass produced 5-kW solid state fuel cell that can be combined like batteries to meet larger power needs.

A number of factors contribute to solid state fuel cell technology being chosen to meet performance goals. The efficiency is inherently high; temperatures are conducive to internal reforming of fuels; materials are compatible with available liquid fuels (gasoline and diesel); heat removal designs are simple, efficient, and enable compact design; power density is very high; and components can be fabricated with advanced manufacturing techniques much like computer chips.

SECA represents a new model for joint government and private industry technology development. The structure of SECA is designed to leverage resources across the federal agencies to overcome the most difficult technology barriers, while enabling private partners to maintain a competitive position.

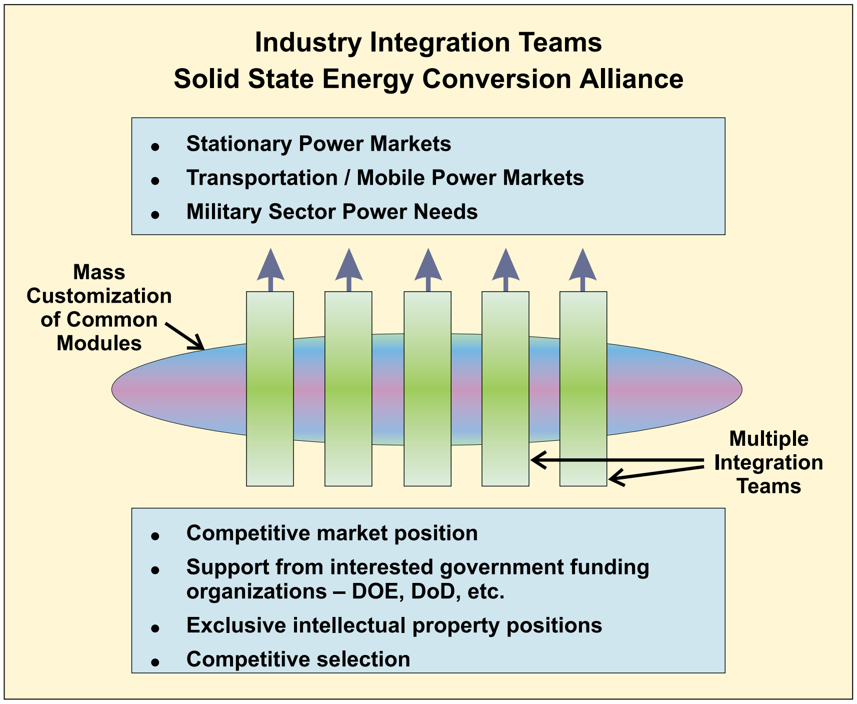
The essence of the SECA organization is integration of a crosscutting core technology program (involving universities, National Laboratories, and other research-oriented organizations) with industry development team efforts to design and produce the commercial systems. The core technology research to address fundamental barriers is made available to the industry teams, and the industry teams provide input to core technology research direction. Industry teams are to be selected through competitive solicitations for cost-shared cooperative agreements. Commercialization decisions to meet market requirements remain the purview of the development teams, with intellectual property protection provided by virtue of their meeting cost-sharing requirements.

The number of teams and program success will be determined in part by the extent of participation by the Department of Defense and other government agencies (coordinated through NETL). The intent is to establish as broad a market as possible to provide the incentive for investment in the manufacturing infrastructure.

A workshop was held in June 2000 to launch the SECA initiative and obtain input for the first program solicitation. After posting a draft solicitation on the NETL web site for comment, the solicitation was issued in Fall 2000. Selections were planned for the end of 2000.

Goals established for the SECA program are $400/kW for stationary applications, with fuel-to-electricity efficiencies of over 40–60 percent by 2010. An interim goal is commercial introduction of an $800/kW solid state fuel cell by 2004, with fuel-to-electricity efficiencies of around 40 percent.

If the technical goals are achieved, fuel cell technology will move from niche markets to widespread use in both stationary and transportation applications. The result will be a revolutionary positive impact on the environment and energy security. Moreover, forging a U.S. industrial base to produce low-cost fuel cells will place the U.S. in a strong position to leverage global markets clamoring for energy. Finally, the solid state fuel cell will become a key Vision 21 enabling technology.



PROGRAM AREAS

In Partnership with Industry

While more than 200 PAFC fuel cells have been manufactured for sale at various locations around the world, a recent installation in New York City's Central Park underscores several important advantages offered by fuel cells.

The DOE, in partnership with the New York Power Authority, installed a 200-kW PAFC in Central Park to provide electricity in the Police Department's 22nd precinct station. Prior to the fuel cell installation, power supply to the 148-year-old precinct station, a converted horse stable, often precluded simultaneous operation of all office equipment. This on-site fuel cell avoided an estimated $1.2 million power line upgrade, provided an inconspicuous clean power supply about as large as a double-size garden shed, and allowed recharging of non-polluting electric vehicles used by the police department. The government provided about one-third of the project cost under a Department of Defense-funded program administered by the DOE.

ONSI Corporation PAFC similar to the unit installed in Central Park.